Altitude and Sport

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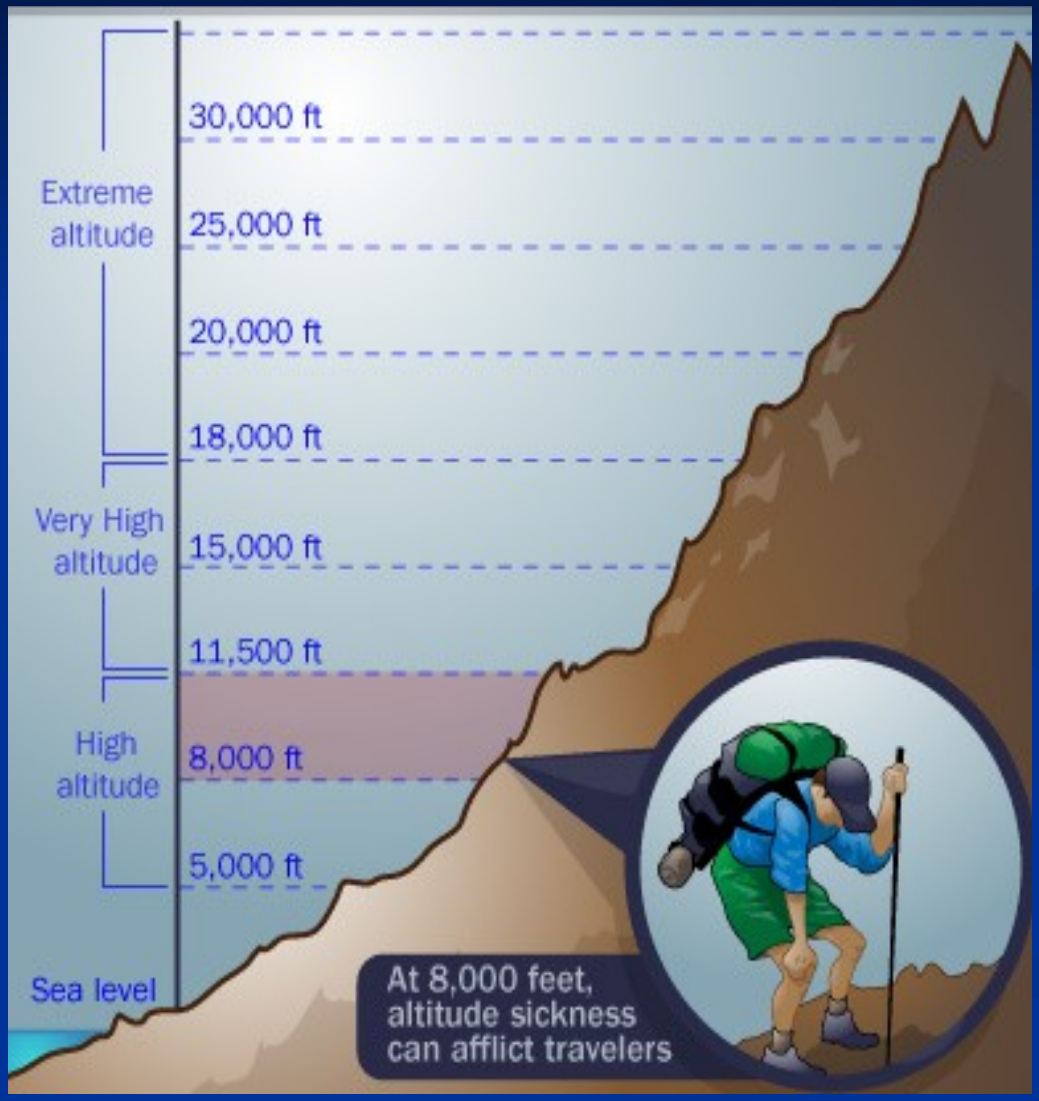
Review objectives

- Physiologic effects of altitude
- Altitude illness
  - AMS/HACE
  - HAPE
  - Return to play/altitude
- Altitude training
  - Use and efficacy of strategies used to improve performance

Altitude



- 1500 – 3500m (4921 – 11483 ft) ‘high altitude’
- 3500 – 5500m (11,483 – 18,045 ft) ‘very high altitude’
- 5500 – 8850m (18,045 – 29,035 ft) ‘extreme altitude’

Environment at Altitude

- PO2 drops exponentially with altitude

  (temperature, distance from equator, season, weather also affect PO2)

- Temperature drops (6.5 C per 1000m)
- UV light penetration increases approximately 4% per 300m
- ‘Dry’ environment with increased water losses thru skin / respiration

Hypobaric Hypoxemic environment

- The key issue! Oxygen is life
- The unifying cause for High Altitude Illness syndromes

www.altitude.org/calculators

Acclimatization

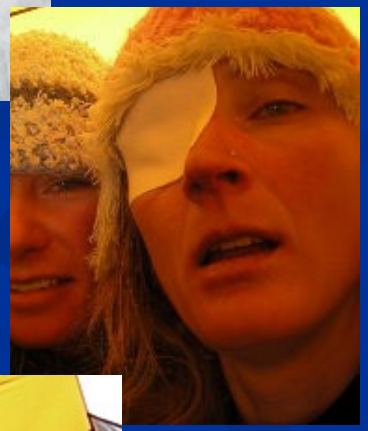
- Process of physiologic adaptations to protect body in hypoxic environment
  - Immediate
    - Hypoxic Ventilatory response (HVR)
    - Increased sympathetic tone
    - Hypoxic Pulmonary Vasoconstriction Response (HPVR)
    - Bicarb diuresis
  - Delayed
    - Erythropoetin increases
    - Tissue/muscle adaptation
    - Pulmonary arteriole muscle remodeling

Acclimatization

- Acclimatization time varies between individuals – usually takes several days
- Additional time for gains in elevation
- Body capable of acclimatization to elevations up to 5500m

Additional Hazards at Altitude

- Dehydration
- Hypothermia/frostbite
- Ocular conditions
  - UV photokeratitis
  - Ocular palsy, cortical blindness, retinopathy
- Disordered sleep
- Thrombotic event



High Altitude Illness (HAI)

- Cerebral and Pulmonary illness syndromes due to effects of hypobaric hypoxia
  - Acute Mountain Sickness (AMS)
  - High Altitude Cerebral Edema (HACE)
  - High Altitude Pulmonary Edema (HAPE)

Risk Factors for HAI

- Elevation and ascent rate**
- Personal hx of prior HAI

  (Genetic predisposition)

PRIMARY

- Exertion at altitude
- Medications / ingestants suppressing ventilatory drive (Narcs, sleepers, EtOH)
- Chronic medical conditions contributing to pulmonary hypertension
- Obesity?

SECONDARY

Pathophysiology of HAI

Current evidence points to process of capillary leak and/or permeability

- Blood/brain barrier (AMS/HACE)
- Alveolar/capillary (HAPE)

Hypobaric-hypoxic induced vascular flow changes and increases in hydrostatic pressure

Clinical approach to HAI

Diagnosis

- Index of suspicion
- Lake Louise Diagnostic Criteria (1992)

http://www.high-altitude-medicine.com/

Treatment

- Facilitate Acclimatization
- Improve Oxygenation
  - Modify environment
  - Modify behavior
  - Medication use

Acute Mountain Illness – AMS

(Lake Louise criteria)

- Defined as HEADACHE plus one or more symptom:
  - Anorexia, nausea or vomiting
  - Fatigue or weakness
  - Dizziness or lightheaded
  - Difficulty sleeping

***in the setting of recent ascent*

AMS features

- 25 – 67% incidence
- Occurs relatively soon after ascent
  - (6-10 hrs)
- Abates usually within 3 days
  - (if no further ascent)
- Symptoms range mild (annoyance) to moderate (performance affecting)
- Good treatment response / prognosis

- WARNING!! May progress to HACE

Treatment - AMS

Mild symptoms:

- Halt ascent, rest, acclimatize
- Descend ≥ 500 m
- Acetazolamide 125-250mg po bid

Moderate /severe symptoms:

- Descend ≥ 500 m
- Low-flow oxygen 1-2 L/min
- Portable hyperbaric chamber
- Acetazolamide 125-250mg po bid
- Dexamethasone 4mg (PO/IM) q 6h

**Use combination of approaches until symptoms resolve

Portable Hyperbaric Chamber
(2 PSI simulates 2000m descent)

High Altitude Cerebral Edema – HACE (Lake Louise criteria)

- Presence of a change in mental status and/or ataxia in a person with AMS

OR

- Presence of both mental status changes andataxia in a person without AMS

HACE features

- Occurs in < 1% of those going to altitude
  - More common with AMS (3.4%) and HAPE (13-20%)
- Ataxia & Altered consciousness hallmark signs
- Usually takes several days (1-3) to present
- Usually at very high/extreme altitude but has been reported below 3000m
- May be FATAL if unrecognized/untreated (due to brain herniation from cerebral edema)
- Partial to full recovery over several weeks

Treatment - HACE

- Immediate descent > 1000 m
- Oxygen to maintain SaO_2 >90%
- Dexamethasone – 8 mg (PO/IM /IV) initially followed by 4 mg qid
- Portable hyperbaric therapy if descent impossible

High Altitude Pulmonary Edema – HAPE

(Lake Louise criteria)

- Defined by at least 2 pulmonary signs **AND** 2 pulmonary symptoms

Signs

- Crackles
- Wheezing
- Cyanosis
- Tachypnea
- Tachycardia

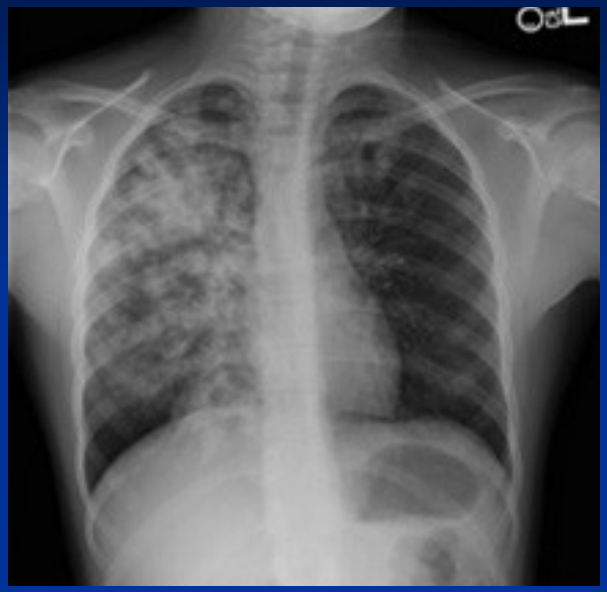
Symptoms

- Cough
- Dyspnea at rest
- Exercise intolerance
- Chest tightness or congestion

HAPE features

- Occurs < 1% of visitors to altitude
  - Higher incidence (4-15%) at very high/extreme altitude
- Leading cause of death among HAI – syndromes
- Usually takes several days (2-4) to present
- Symptoms worse at night due to additive effects of disordered sleep (lower PaO2)
- Of those who get HAPE – 50% will have AMS
- Full recovery time dependent on early recognition and appropriate treatment (days to weeks)

HAPE



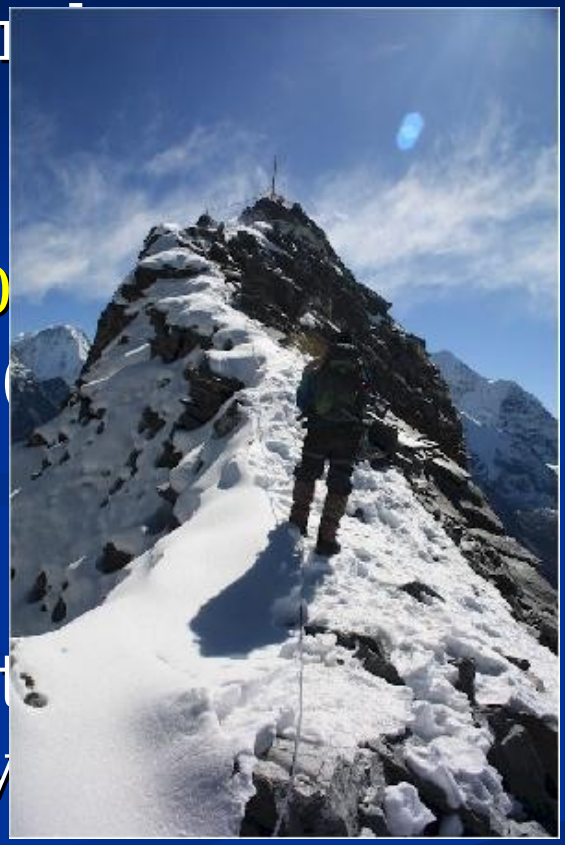
- Severe hypoxemia
- Congested wet cough, rales, wheezing
- Patchy infiltrates on CXR
- Dyspnea, tachycardia
- Weakness

Treatment - HAPE

- Oxygen to maintain SaO2 > 90%
  - (4-6 L/min until improved, then 2-4 L/min)
- Descent > 500-1000m
- Portable hyperbaric chamber if descent delayed
  - (2-4 psi continuously)
- REST…decrease exertional activity
  - Consider nifedipine (20 - 30 mg SR q 12 h)
  - Consider salmeterol 125 mcg bid
  - Consider expiratory positive airway pressure mask
  - Dexamethasone IF HACE develops

Preventing HAI syndromes

- Adherence to Ascent rate a
  Acclimatization protocol
  1) < 600m day
  2) Rest day for every 600-120
- Residence at elevation >90
- Avoid overexertion
- Sleep at lower elevation
- Use of prophylactic medica
  (for those with history



****physical fitness is NOT protective**

Medication prophylaxis

- AMS – HACE
  - Acetzolamide: 125 – 250 mg bid 1 day prior to ascent and for 2 days at altitude
  - Dexamethsone: 2mg q 6hr or 4mg q 12hr

Medication prophylaxis

- HAPE
  - Nifedipine: 20-30mg extended release bid
  - Salmeterol: 125mcg inh bid
  - Phosphodiesterase inhibitor (Tadalafil): 10mg bid

Acetazolamide / Dexamethasone:
Positive preliminary studies – may consider

Predicting HAI susceptibility

Tannheimer et al. (2009) *Testing Individual Risk of Acute Mountain Sickness at Greater Altitudes* MILITARY MEDICINE,174. 4:363.

Subjects: 36 Acclimatized elite level soldi

Test: Lowest SaO2 level combined with ti
needed to complete a 46 meter uph
run at altitude

Outcome: Incidence/severity of HAI symp
on altitude symptom questiona

Result: Correlation between incidence/se
of HAI syndrome and low SaO2 an
greater the time to complete run

Return to Altitude after HAI

- Considerations
  - Severity and type of prior HAI
  - Activity requirements
    - Altitude & Ascent rate
    - Exercise type/duration
  - Feasibility of descent & extra rest days if needed
  - Availability of medical evaluation & treatment

Two scenarios for Return to Altitude Activity after HAI

- Remote history of HAI, fully recovered
- Recent HAI, with/without recovery

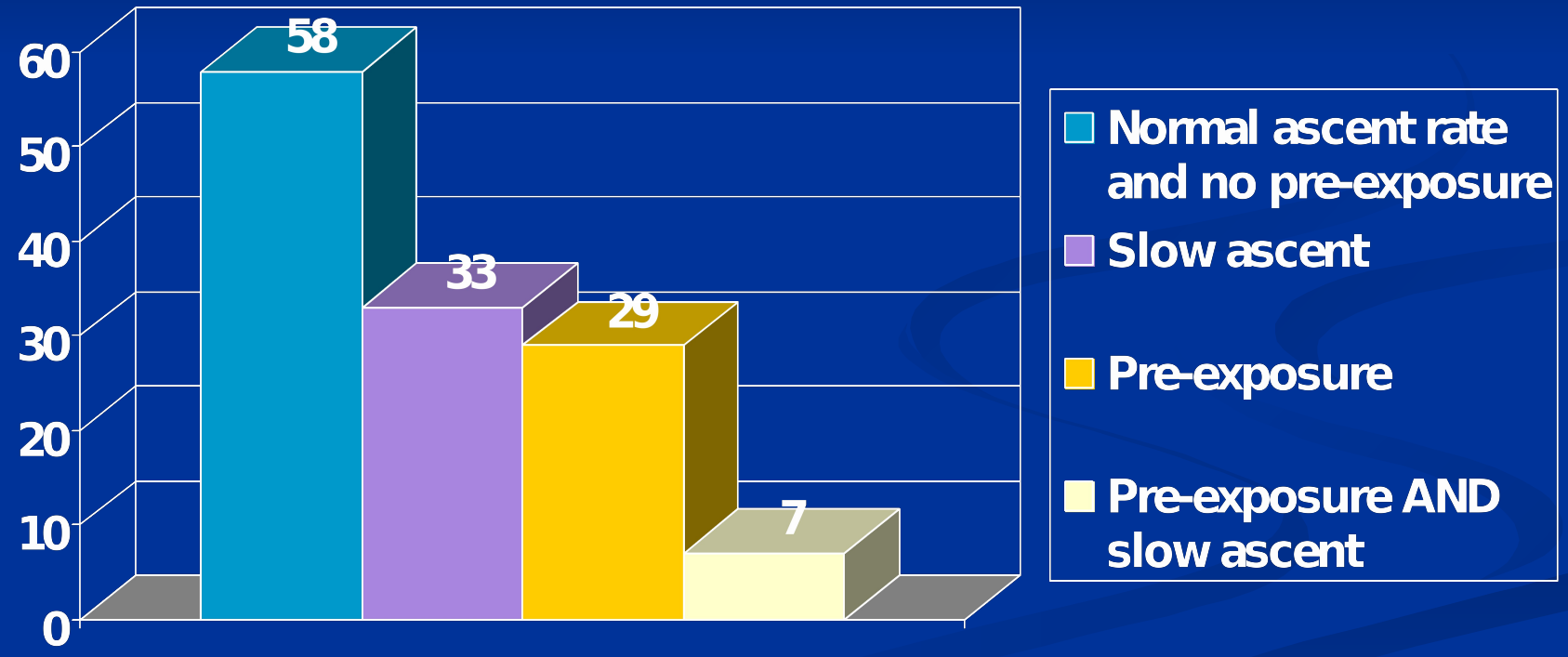
Remote history of HAI, fully recovered

Proper acclimatization protocols paramount

- Ascend no more than 600 m (1970 ft) per day in sleeping altitude when >2500 m (8200 ft)
- Spend one extra night every 600-1200 m (1970 – 3937 ft)
- Avoid abrupt ascent to >3000 m (9843 ft)
- Spend 2-3 nights at 2500-3000 m before ascending further

“Acute mountain sickness: influence of susceptibility, preexposure, and ascent rate”

Incidence of AMS (%) during ascent to 4559 m in persons with a prior history of AMS



Schneider M et al. *Med Sci Sports Exerc* 2002

Remote history of HAI, fully recovered – HAI Prevention Strategy

- Strong recommendation for acclimatization and slow ascent.
  1) < 600m day
  2) Rest day for every 600-1200m
- Consider use of prophylaxis meds singularly or in combination as previously described

(evidence for recommendations limited – case series, small prospective placebo controlled trials, expert opinion)

Recent HAI, with/without full recovery

Additional considerations for recent HAI

- Should the patient **fully** recover before returning to altitude/activity?
- How safe is continued activity at altitude?
- Should activities be limited?

Recent HAI - *Mild* AMS

(No evidence-based recommendations)

- Common practice: continue activity & altitude exposure despite symptoms
- Risks
  - Impaired cognition/performance
  - Progression to moderate AMS or HACE
- Consider starting acetazolamide

Recent HAI - *Moderate* AMS

- Descend >500 m
- Rest 1-2 days
- Do not allow continued ascent/activity
  - Significant performance/cognition decrement
  - Risk of progression to HACE
- Oxygen 1-2 days, if available
- Acetazolamide; dexamethasone as alternate

Recent HAI – HACE / HAPE

(No evidence based recommendations)

- **Full recovery** highly advised
- Strict adherence to acclimatization and slow ascent protocols
  - Ascend < 600 m/day
  - Rest day every 600 – 1200 m
- Consider medication prophylaxis

HACE recovery highly variable

- 1-3 days for symptoms to resolve
- Days to 12 weeks for neuropsychological function to normalize
- 3-4 weeks for papilledema to resolve
- Days to 5 weeks for MRI to normalize

Evidence of Brain Damage after High-altitude Climbing by Means of Magnetic Resonance Imaging

- Only 1 in 13 of the Everest climbers had a normal MRI
- Among remaining amateurs, 5 had subcortical irreversible lesions, and 10 had innumerable widened Virchow-Robin spaces. Conversely, we did not see any lesion in the control group.
- "…conclude that high-altitude climbing carries a non-negligible risk of developing cerebral lesions and atrophy on MR and that the risk looks higher in non-properly acclimatized subjects."

Nicolás Fayed, et al. Am J Med 2006

HAPE recovery

- Variable; evidence in literature case-based
- May take 2 weeks to recover strength
- Resume some activity when SaO_2 > 90% without supplemental O_2
- Remaining at some altitude fosters acclimatization via pulmonary arteriolar remodeling

“Reascent following resolution of high altitude pulmonary edema (HAPE).”

- Case reports of 3 mountaineers with HAPE
- Treated with…
  - descent to lower altitude
  - oxygen
  - rest 2-3 days
- Resumed ascent; no prophyla
  - < 600 m/day ascent; several rest days
- RESULT: all reached peaks w/o HAPE
  - One reached summit of Mt. Everest at 8850 m (29,035 ft)

Litch JA, Bishop R. *High Alt Med Biol* 2001

Altitude Training

Why?

- Acclimatization improves aerobic capacity at altitude
- Acclimatized athletes perform better at altitude

So…acquiring physiologic effects of acclimatization should improve overall athletic performance right?

Let’s see…

Training strategies

- Live HIGH / Train HIGH
- Live HIGH / Train LOW
  - Terrestrial vs artificial
- Live LOW / Train HIGH

Live High / Train High

- Original strategy trial for altitude training
- Variable effect
- Training intensity not equivalent to sea-level
- Potential ining and performa

Live High / Train Low

- Erythrocyte volume
- Hemoglobin concentration
- VO2 max

INCREASES

- Performance result → modest improvements

  - 1-2% on times
  - Olympic medals?

Artificially created altitude

- Nitrogen dilution apartments
- Oxygen filtration apartments
  - Both create hypoxic living condition (2000-3500m)
  - Solves logistics of actual residence at altitude

- Oxygen supplementation
  - Living at altitude but training with O2 (simulates sea level)
  - Used at Colorado Springs Olympic Training Center


COLORADO ALTITUDE TRAINING


HYPOXICO

Live Low / Train High

- IHE: intermittent hypoxic exposure
- IHT: intermittent hypoxic training

  - Dosing variation (hrs/day, # weeks)
  - Minimal hematologic/VO2 max/performance changes
  - Effective for pre-acclimatization
  - ? Tissue effect (increased skeletal muscle mitochondrial density, capillary to fiber ratio, fiber area)

Altitude Training Bottom Line

- Altitude training is being utilized
  - Experimental phase – growing data
  - Best suited for elite level/high competitive athlete
- LH + TL seems to have better data
  - Hematologic changes, VO2 max, performance
- Best strategy for competing at altitude is to arrive early and Acclimatize

Summary

- Acclimatization is powerful adaptation
  - Improves SaO2 / VO2 at altitude (up to 5500m)
  - Variable between individuals
  - First line prevention/treatment HAI
- HAI result of hypobaric hypoxia
  - Inconvenient to dangerous (AMS to HAPE/HACE)
  - Rest, descent, O2 – Key treatments
  - Meds utilized as adjuvants

Summary

- Altitude Training
  - LH + TL seems to be best strategy
  - Early arrival and acclimatization to venue environment

Questions

DOUBT

In the Battle between You and the World,
Bet on the World.